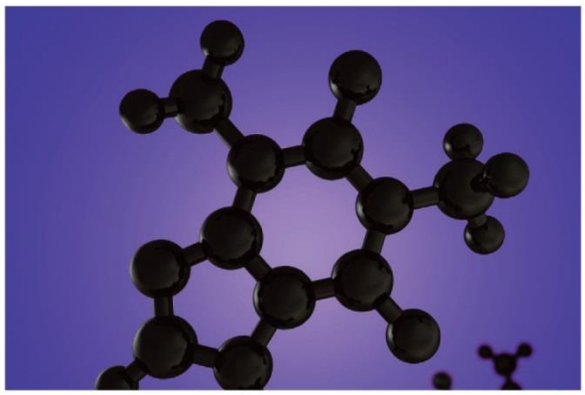
Canadian Food Inspection Agency
Agence canadienne d'inspection des aliments

Food Safety Action Plan

REPORT

2011-2013 Targeted Surveys

Chemistry



Acrylamide in Selected Foods

TS-CHEM-11/13

Canada

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Executive Summary

The Food Safety Action Plan (FSAP) aims to modernize and enhance Canada's food safety system. As part of the FSAP enhanced surveillance initiative, targeted surveys are used to generate data in order to evaluate various foods for specific hazards.

Acrylamide may be unintentionally formed in carbohydrate-rich foods that are cooked at high temperatures (e.g. fried, baked, toasted, grilled, or roasted), and/or processed at lower temperatures (e.g. sterilized, dried, preserved). Additionally, acrylamide may be present in bottled water if the source water has been treated with acrylamide-containing coagulants. Acrylamide is classified as 'probably carcinogenic to humans' by the International Agency for Research on Cancer. Health Canada's Bureau of Chemical Safety concurs with the opinion of the Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives which have indicated that the current levels of acrylamide exposure from food represent a potential human health concern.

The main objectives of the 2011-2013 FSAP Acrylamide in Selected Foods survey were to generate baseline surveillance data on acrylamide levels in a defined set of food commodities, and to compare these levels to the previous FSAP survey on acrylamide (2010-11) and to similar surveys performed by Health Canada (HC) and the U.S. Food and Drug Administration (FDA).

There are currently no regulations in Canada specifying maximum levels of acrylamide in foods. There are, however, guidelines in the United States limiting the use of acrylamide-based coagulants for the treatment of drinking water. Additionally, the European Union has established a set of indicative levels designed to trigger investigations into food products containing elevated levels of acrylamide. As part of ongoing efforts to limit intake of acrylamide to "As Low As Reasonably Achievable" (ALARA Principle) levels, there are several guidance documents available: the Code of Practice for the Reduction of Acrylamide in Foods (CAC/RCP 67-2009) from Codex Alimentarius and the 2013 Acrylamide Toolbox from FoodDrinkEurope are two internationally-recognized examples. Health Canada's Bureau of Chemical Safety has also published acrylamide reduction strategies that consumers can follow when preparing foods in the home. Given the wide variety of processes, procedures, and types of raw materials, the means of implementing the ALARA Principle will be company-specific.

A total of 2284 food products were sampled and tested for acrylamide content. The food products were divided into three main categories: grain-based foods, fruit/vegetable-based foods, and assorted foods (e.g. syrup/molasses, bottled water). Most of the samples tested (87%) contained detectable levels of acrylamide. More specifically, 72% of assorted foods, 84% of fruit/vegetable-based foods, and 95% of grain-based foods tested positive for acrylamide. The acrylamide levels ranged from the method reporting limit of 5 parts-per-billion (ppb) to a maximum of 7100 ppb. The category with the highest

average acrylamide level was syrup/molasses (1289 ppb), while the category with the lowest average acrylamide level was infant cereal (18 ppb).

In general, the prevalence of acrylamide and the range of observed acrylamide levels were comparable between the current and previous FSAP surveys and in comparison to HC and FDA surveys for similar products.

All the data generated were shared with Health Canada's Bureau of Chemical Safety for use in performing human health risk assessments. Health Canada indicated that, given the chronic nature of the potential hazard represented by acrylamide and considering the overall levels of acrylamide found, the levels of acrylamide observed in this survey would not be expected to pose a safety concern. Health Canada continues to encourage the food industry to further pursue reduction efforts for acrylamide in processed foods. Health Canada's on-going risk management efforts relating to acrylamide in foods may also involve follow-up with food manufacturers when products are found to contain notably and/or consistently elevated levels of acrylamide relative to other, similar foods available on the Canadian market.

1. Introduction

1.1. Food Safety Action Plan

In 2007, the Canadian government launched a five-year initiative in response to a growing number of product recalls and concerns about food safety. This initiative, called the Food and Consumer Safety Action Plan (FCSAP), aims to modernize and strengthen Canada's safety system for food, health, and consumer products. The FCSAP initiative unites multiple partners in ensuring safe food for Canadians.

The Canadian Food Inspection Agency's (CFIA) Food Safety Action Plan (FSAP) is one element of the government's broader FCSAP initiative. The goal of FSAP is to identify risks in the food supply, limit the possibility that these risks occur, improve import and domestic food controls, and identify food importers and manufacturers. FSAP also looks to verify that the food industry is actively applying preventive measures, and that there is a rapid response when/if these measures fail.

Within the current regulatory framework, some commodities (such as meat products) traded internationally and interprovincially are legislated by specific Acts. These are referred to as federally registered commodities. Under the current regulatory framework, the non-federally registered commodities encompass 70% of domestic and imported foods and are regulated solely under the *Food and Drugs Act* and *Regulations*. Targeted surveys are primarily directed towards non-federally registered commodities.

1.2. Targeted Surveys

Targeted surveys are pilot surveys used to gather information regarding the potential occurrence of chemical residues, contaminants, and/or natural toxins in defined food commodities. The surveys are designed to answer specific questions. Therefore, unlike monitoring activities, testing of a particular chemical hazard is targeted to commodity types and/or geographical areas.

Due to the vast number of chemical hazards and food commodity combinations, it is not possible, nor should it be necessary, to use targeted surveys to identify and quantify all chemical hazards in foods. To identify food-hazard combinations of greatest potential health risk, the CFIA uses a combination of scientific literature, media reports, and/or a risk-based model developed by the Food Safety Science Committee comprised of federal, provincial and territorial subject matter experts in the area of food safety. The Committee deemed acrylamide as a high priority[1].

1.3. Acts and Regulations

The *Canadian Food Inspection Agency Act* stipulates that the CFIA is responsible for enforcing restrictions on the production, sale, composition, and content of foods and food products as outlined in the *Food and Drugs Act* and *Regulations*.

Health Canada's Bureau of Chemical Safety establishes the health-based maximum levels for chemical residues and contaminants in food sold in Canada. Currently, no maximum level, tolerance, or standard has been established by Health Canada's Bureau of Chemical Safety for acrylamide levels in food and therefore, assessing compliance with a Canadian numerical standard was not possible. However, all foods sold in Canada must comply with the provisions in section 4(a) of the *Food and Drugs Act*, which prohibit the sale of food that has in or on it any poisonous or harmful substance.

Elevated levels of acrylamide in specific foods are brought to Health Canada's attention and are assessed by Health Canada's Bureau of Chemical Safety on a case-by-case basis using the most current scientific data available. Follow-up actions are initiated in a manner that reflects the magnitude of the health concern. Actions may include further analysis, notification of the producer or importer, follow-up inspections, additional directed sampling, and recall of products.

2. Survey Details

2.1. Acrylamide

Acrylamide is an industrial chemical produced for a variety of uses, such as water treatment and the production of glue, paper and cosmetics. It may also be formed unintentionally in plant-based carbohydrate-rich foods which are cooked or processed at elevated temperatures before consumption (e.g., fried, baked, toasted, grilled, and roasted). To form acrylamide, food must contain appreciable levels of both the amino acid asparagine and sugars. When heated, the asparagine and sugars may react to form acrylamide[2,3,4,5].

In addition to high temperature formation, acrylamide has been detected in foods processed at much lower temperatures (70-80°C), as is the case for many dried, canned, and/or sterilized fruit and vegetable products[6]. Acrylamide is also a raw material used in the manufacture of coagulants for drinking water treatment. Residual acrylamide may remain in the coagulants as an impurity, leading to the potential for acrylamide contamination of bottled water products[7].

Acrylamide is classified as 'probably carcinogenic to humans' by the International Agency for Research on Cancer[8]. Some studies have suggested a correlation between dietary intake of acrylamide with endometrial, ovarian[9], breast[10], and renal cancers[11].

However, a recent review of epidemiological studies found no conclusive link between dietary acrylamide and cancers in humans[12].

Health Canada's Bureau of Chemical Safety, governments in other countries, and international committees established by the World Health Organization (WHO) and the United Nations Food and Agriculture Organization (FAO) continue to monitor dietary exposure to acrylamide and to monitor and/or conduct toxicological research[13]. There are guidelines in the United States limiting the use of acrylamide-based coagulants for the treatment of drinking water[7]. Additionally, the European Union has established a set of indicative levels designed to trigger investigations into food products containing elevated levels of acrylamide[14].

2.2. Rationale

Acrylamide is commonly detected in carbohydrate-rich plant-based foods cooked at high temperatures (e.g., deep-fried French fries, potato and vegetable chips, breakfast cereals, pastries, cookies, breads, rolls, cocoa, roasted nuts, and roasted coffee)[4]. In addition, acrylamide has been detected in low-temperature processed foods that are dried, canned, or preserved (e.g., olives, dried fruits, and jarred infant food) [6,15,16]. As many of these foods are frequently consumed by Canadians, Health Canada's Bureau of Chemical Safety has been engaged in raising awareness and providing information to consumers and the food industry about ways to reduce the formation of acrylamide during food preparation and processing[17,18,19,20].

This survey examined acrylamide levels in high carbohydrate foods such as vegetable chips/sticks, corn chips, breakfast cereals, granola bars, cookies, crackers/crispbreads/croutons, infant biscuits, infant cereal, nut butters, sweet potato products, and soft breads. Samples of dried or preserved fruit/vegetable products (prunes, jarred infant food, and olives) and unbrewed coffee were also examined. Bottled water was included, as low levels of acrylamide could be present in bottled water if the source water has been treated with acrylamide-containing chemicals. All commodities tested herein were selected in consultation with Health Canada's Bureau of Chemical Safety in order to address data gaps and/or better characterize the acrylamide levels in certain foods.

The current targeted survey complements Health Canada's Bureau of Chemical Safety's Acrylamide Monitoring Program[13] by examining a greater number of samples and a broader range of products and brands. This targeted survey also adds to baseline data established in the previous CFIA FSAP targeted survey[21] on the levels of acrylamide in a wider variety of foods than previously examined.

2.3. Sample Distribution

The 2011-2013 acrylamide survey targeted domestic and imported high carbohydrate foods and dried/preserved fruit and vegetable products. All foods were sampled at grocery and specialty stores in 11 Canadian cities from April, 2011 to January, 2013. A

total of 2284 samples (642 domestic, 1105 imported, and 537 of unspecified origin) were tested for acrylamide. In general, an unspecified country of origin refers to those samples for which the origin could not be determined from the product label or sample information. It is important to note that the products sampled often contained the statement "imported for Company A in Country Y" or "manufactured for Company B in Country Z", and though the labelling meets the intent of the regulatory standard, it does not specify the true origin of the product ingredients. Only those products labelled with a clear statement of "Product of", "Prepared in", "Made in", "Processed in", and "Manufactured by" were considered as being from a specific country of origin. The samples originated in at least 46 countries, with the US accounting for 38% of the imported samples.

2.4. Method Details

Samples were analyzed by an ISO 17025 accredited laboratory under contract with the Government of Canada. The laboratory used a Liquid Chromatography Mass Spectrometry method based on a method developed by Health Canada[20]. The method reporting limit was 5 ppb for all matrices.

Samples were tested as sold, meaning that the product was not prepared as per the package instructions, if applicable. Most of the samples were considered ready-to-consume, with the exception of coffee and infant cereals.

2.5. Limitations

The current targeted survey was designed to provide a snapshot of acrylamide levels in selected foods available on the Canadian retail market. In comparison to the total number of such products available to Canadian consumers, a sample size of 2284 is considered small. Therefore, care must be taken when interpreting and extrapolating these results. Regional differences, impact of product shelf-life, packaging and storage conditions, or cost of the commodity on the open market were not examined in this survey. As the samples were picked up at retail, there is no information readily available on the conditions (e.g., temperature, duration) during processing or on the levels of asparagine in the raw materials. It is not possible to definitively determine the causes of differences in acrylamide levels between product types or within a product type.

3. Results and Discussion

3.1. Overview of Survey Results

Samples analyzed in the current survey were separated into three groups of products: assorted foods, fruit/vegetable-based foods, and grain-based foods. Of the 2284 samples tested for acrylamide, 1983 samples (87%) had detectable levels of acrylamide. Figures 1, 2, and 3 illustrate the number of samples with a detectable level of acrylamide as a

function of product group: assorted foods, fruit/vegetable-based foods, and grain-based foods, respectively.

Assorted Foods

The assorted foods category (378 samples) included syrup/molasses, bottled water, unbrewed coffee, and nuts/nut butters (including seed pastes). Acrylamide was not detected in any of the bottled water samples, while all samples of unbrewed coffee contained detectable levels of acrylamide. The highest average level of acrylamide was found in syrup/molasses (1289 ppb).

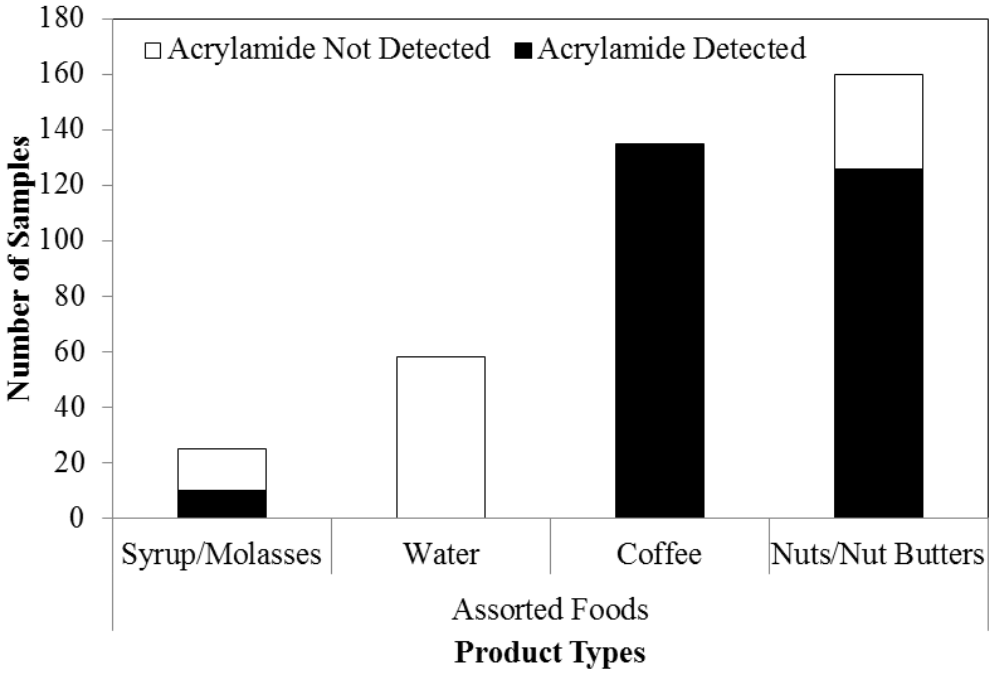


Figure 1. Number of samples for assorted foods by product type (in order of increasing number of samples)

Fruit/Vegetable-Based Foods

Fruit/vegetable-based foods (866 samples) included chips (vegetable, corn, and potato), sweet potato products, olives, prunes, jarred infant food (e.g. puréed fruit/vegetables) and popcorn (popped and unpopped). All samples of potato and corn chips tested positive for acrylamide whereas only 31% of jarred infant food samples tested positive. The highest average level of acrylamide was found in vegetable chips/sticks (921 ppb).

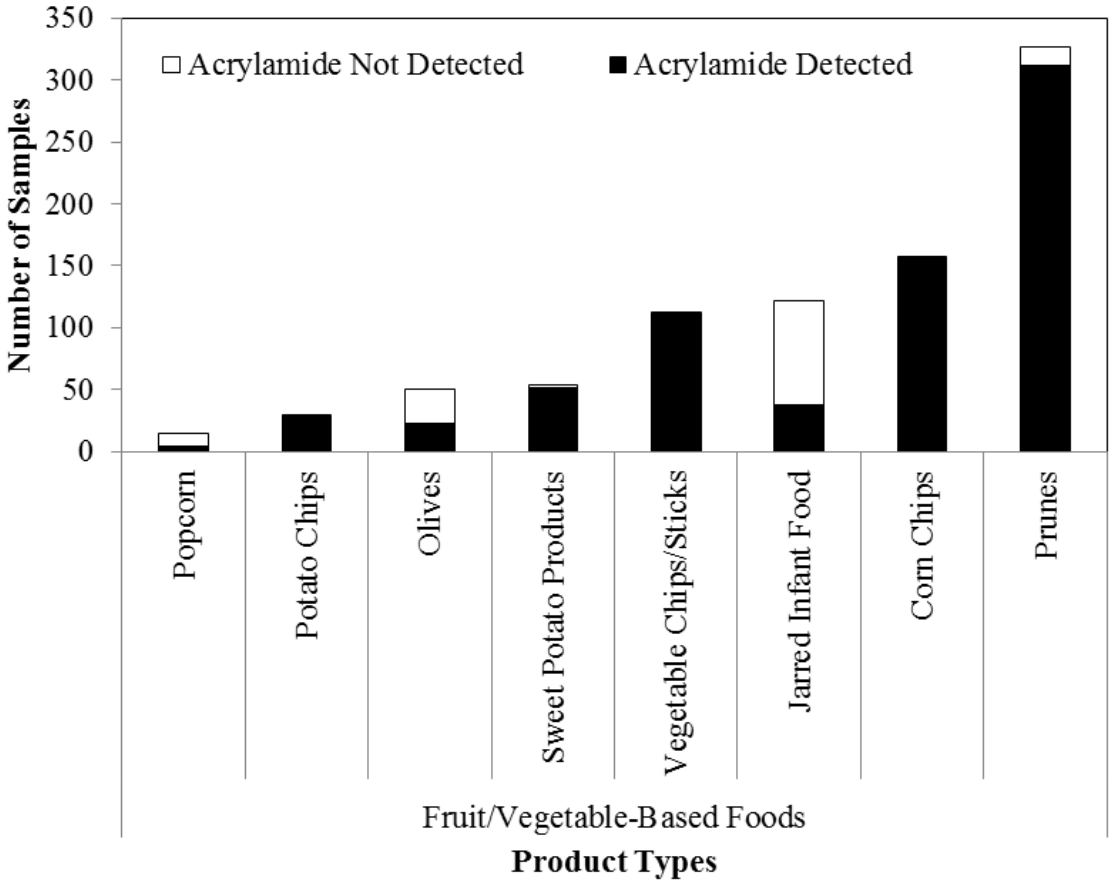


Figure 2. Number of samples for fruit/vegetable-based foods by product type (in order of increasing number of samples)

Grain-Based Foods

Grain-based foods (1040 samples) included cookies, crackers, breakfast cereal, granola bars, infant biscuits, soft breads and infant cereals. Almost all (99%) of crackers and infant biscuits tested positive for acrylamide whereas only 48% of infant cereals tested positive. The highest average level of acrylamide was found in cookies (511 ppb) whereas infant cereals exhibited the lowest average acrylamide level (18 ppb).

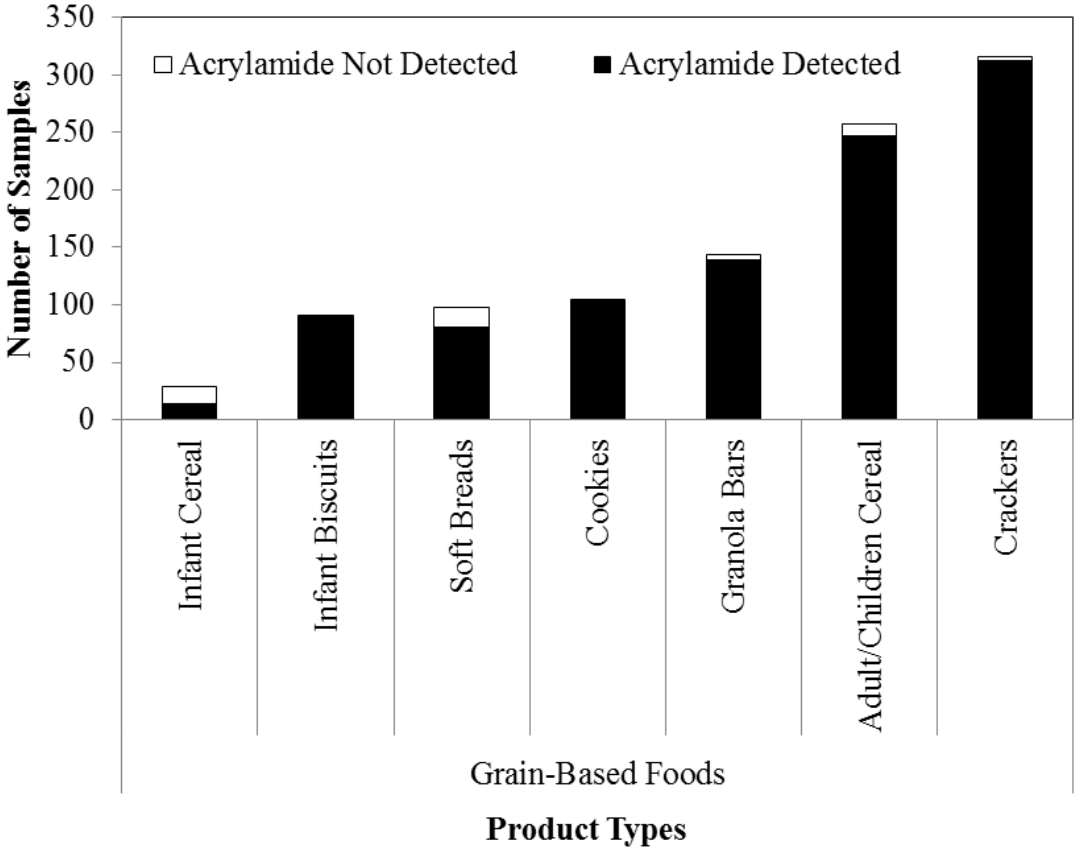


Figure 3. Number of samples for grain-based foods by product type (in order of increasing number of samples)

Table 1 shows the minimum, maximum, and average levels of acrylamide by product type. The measured levels of acrylamide ranged from 5 ppb to 7100 ppb. It should be noted that the average acrylamide levels discussed below were calculated using only those samples for which acrylamide was detected (i.e., average of the positive results only). The average acrylamide level by product type ranged from 18 ppb in infant cereal to 1289 ppb in syrup/molasses. All products selected for sampling were anticipated to contain acrylamide; therefore, the positive rates (percentage of samples with detectable levels) were expected to be high. The positive rate was lower for assorted foods as none of the bottled water samples contained detectable levels of acrylamide.

Table 1. Minimum, maximum, and average acrylamide levels detected in food samples (in order of decreasing maximum acrylamide level per category)

Product Type	Number of Samples	Number (%) of Samples with Detectable Levels	Minimum (ppb)	Maximum (ppb)	Average* (ppb)
Grain-Based Foods					
Cookies	105	103 (98)	10	7100	511
Crackers**	316	313 (99)	6	5700	213
Adult/Children Cereal	257	247 (96)	5	1300	123
Granola Bars	144	139 (97)	5	880	91
Infant Biscuits	91	90 (99)	11	540	223
Soft Breads	98	81 (83)	7	120	31
Cereal - Infant	29	14 (48)	7	79	18
Total (Grain-based Foods)	**1040**	**987 (95)**	**5**	**7100**	**188**
Fruit/Vegetable-Based Foods					
Vegetable Chips/Sticks	112	111 (99)	9	3400	921
Sweet Potato Products	54	51 (94)	5	3300	435
Potato Chips	29	29 (100)	130	2300	536
Corn Chips	158	158 (100)	25	1600	335
Olives	50	22 (44)	15	970	336
Prunes	327	312 (95)	6	910	133
Jarred Infant Food	122	38 (31)	7	370	41
Popcorn	14	4 (29)	58	240	121
Total (Fruit/Vegetable-based Foods)	**866**	**725 (84)**	**5**	**3400**	**336**
Assorted Foods					
Syrup/Molasses	25	10 (40)	17	3200	1289
Nuts/Nut Butters	160	126 (79)	5	1800	129
Unbrewed Coffee	135	135 (100)	53	720	154
Water	58	0 (0)	< LOD	NA	NA
Total (Assorted Foods)	**378**	**271 (72)**	**5**	**3200**	**184**
Overall	**2284**	**1983 (87)**	**5**	**7100**	**241**

*Average of positive results only

**Crackers include crackers, crispbreads, croutons, and rice chips

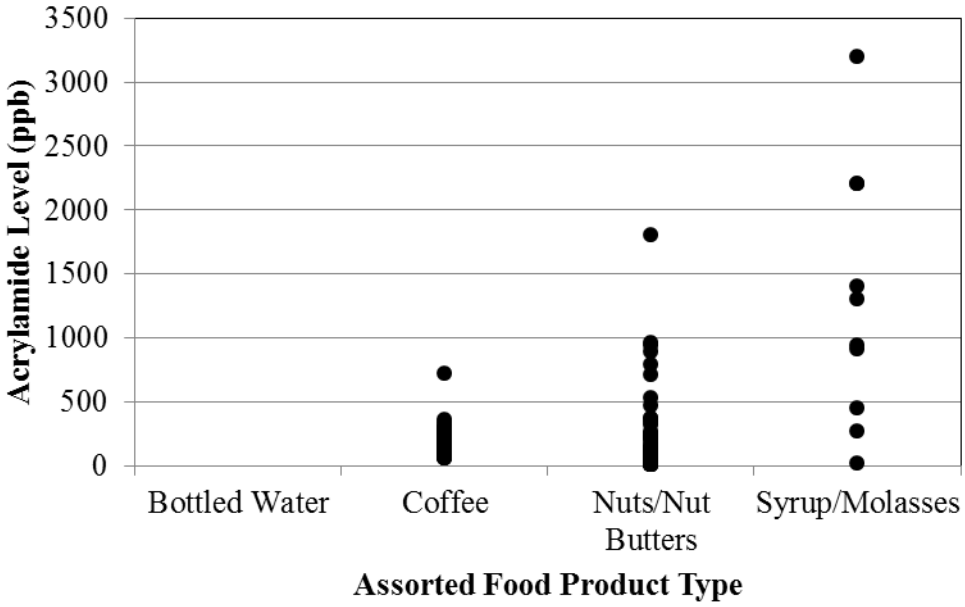
Health Canada's Bureau of Chemical Safety determined that the levels of acrylamide in all foods in this survey were consistent with other results from Health Canada's acrylamide monitoring program and therefore do not raise any particular human health concerns other than what was already identified by Health Canada in its 2012 Revised Exposure Assessment of Acrylamide in Food[22]. No product recalls were warranted given the lack of any new health concerns. Health Canada's on-going risk management efforts relating to acrylamide in foods may also involve follow-up with food manufacturers when food products are found to contain notably and consistently elevated levels of acrylamide relative to other, similar foods available on the Canadian market.

3.2. Survey Results by Product Type

More detailed results by product type are presented and discussed in the following sections. The results from the current survey are bolded and italicised in each table to facilitate comparison. The results of the survey were compared with the acrylamide levels reported in the previous FSAP survey[21], with Health Canada's Bureau of Chemical Safety's recent exposure assessment[22], with recent U.S. Food and Drug Administration (FDA) surveys[14,23] , and with a U.K. Food Standards Agency (FSA) survey[24]. It should be noted that the average results for the FDA surveys were calculated by CFIA staff as the mean of the positives based on the individual reported results. For the HC study, if acrylamide levels were reported as less than the analytical instrument's limit of detection (LOD), the level of acrylamide in the food was conservatively set to the LOD and so, the mean values reported in the HC study are expected to be lower than the CFIA surveys if the positive rate is less than 100%. Also, acrylamide levels are known to vary widely from product to product, from brand to brand and from lot to lot[22].

3.2.1. Assorted Foods

The assorted foods category (Figure 4) included 25 syrup/molasses samples, 58 samples of bottled water, 160 nut/nut butters (including seed pastes), and 135 coffee samples (unbrewed). None of the bottled water samples tested positive for acrylamide. Figure 4 shows the distribution of observed acrylamide levels per product type. The observed acrylamide levels ranged from the method reporting limit of 5 ppb to a maximum of 3200 ppb in syrup/molasses.



Note: Only values above the limit of detection are displayed in the graph

Figure 4. Acrylamide levels in assorted foods by product type (arranged in order of increasing maximum acrylamide level)

Bottled Water

Bottled water was not included in either the Health Canada's Bureau of Chemical Safety[22] or FDA[14,23] surveys. Acrylamide was not detected in any of the 58 samples of bottled water analyzed for the current survey. This is consistent with the results reported by the World Health Organization[25].

Unbrewed Coffee

A total of 135 unbrewed coffee samples were tested for acrylamide, including caffeinated and decaffeinated instant coffee, ground coffee, espresso grind and whole roasted coffee beans. The average acrylamide content by product form (ground, bean, instant, espresso) is shown in Figure 5. Here, "Unknown" refers to samples where the product form could not be determined from the product label. Samples of whole coffee beans had the lowest average acrylamide level (116 ppb) whereas espresso samples had the highest average level (200 ppb). There appeared to be minimal difference in acrylamide levels between caffeinated and decaffeinated products in the current survey.

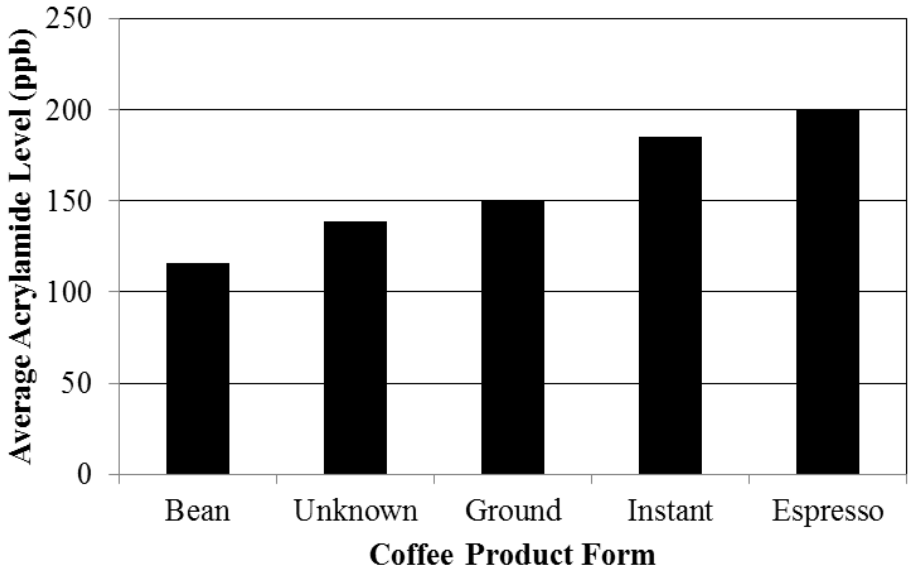


Figure 5. Average acrylamide levels in unbrewed coffee samples by product type (arranged in order of increasing average acrylamide level)

Table 2 presents a comparison of the acrylamide levels for coffee in the current FSAP survey on acrylamide to an FDA survey, which included caffeinated and decaffeinated ground/instant coffee powders and brewed coffee. The current study exclusively tested unbrewed coffee; therefore, only the FDA results for unbrewed samples are used for comparison. The CFIA and FDA found acrylamide in all samples of unbrewed coffee. The CFIA maximum acrylamide level in unbrewed coffee is slightly higher than the FDA survey however the average is lower.

Table 2. Summary of FSAP and FDA surveys examining acrylamide levels in unbrewed coffee

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average * (ppb)
Unbrewed Coffee**						
CFIA	***2011-2013***	***135***	***135 (100)***	***53***	***720***	***154***
FDA[14]	2011	76	76 (100)	27	609	222

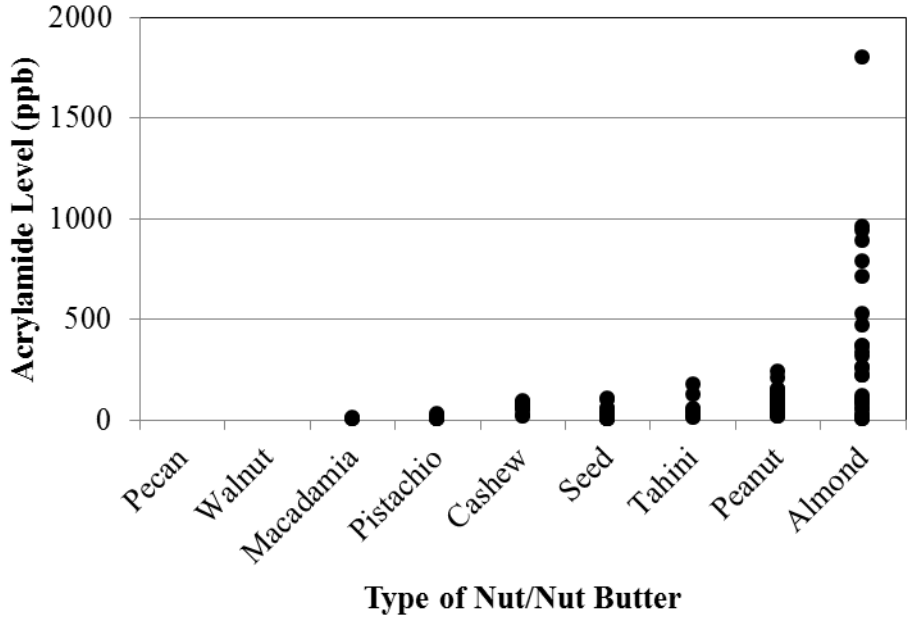
*Average of positive results only

**Only unbrewed coffee samples from the FDA survey are included for comparison

Nuts/Nut Butters

The nuts/nut butters category included whole roasted and raw nuts (e.g., peanuts, almonds, walnuts, macadamia nuts) as well as nut butters (e.g., peanut butter, almond butter, walnut butter). Also included in the nut/nut butters category were pastes/butters of seeds (e.g., tahini). Figure 6 illustrates the distribution of acrylamide levels in nuts/nut

butters by nut/seed type. No samples of walnut or pecan nut/nut butters tested positive for acrylamide. The highest levels of acrylamide were observed in whole roasted almonds and almond butter, with a maximum detected value of 1800 ppb and an average of 344 ppb.



Note: Only values above the limit of detection are displayed in the graph

Figure 6. Acrylamide levels in nuts/nut butters by nut type (arranged in order of increasing maximum acrylamide level)

To facilitate comparison with data reported by HC and the FDA, peanuts/peanut butter samples are discussed separately from other nuts/nut butters (e.g., almonds, cashews, macadamia, pecans, and walnuts). A total of 40 peanut/peanut butter and 120 other nuts/other nut butters were tested for acrylamide. For all of the types of nuts sampled in the current survey, the maximum and average levels of acrylamide were higher for nut butters than whole nuts.

Peanuts/Peanut Butter

One-hundred percent of whole peanuts and peanut butter samples tested positive for acrylamide, with average levels of 28 ppb and 93 ppb, respectively. Table 3 summarizes the current FSAP survey data as well as HC and FDA data on acrylamide levels in peanuts and peanut butter. For whole peanuts, the current results match well with the HC and FDA data. The current survey data for peanut butter has a higher maximum detected level but a very comparable average. The positive rate for peanuts and peanut butter in all cases is 100%, except for the FDA survey of whole peanuts (note the small sample size).

Table 3. Summary of FSAP, HC and FDA surveys examining acrylamide levels in peanuts and peanut butter

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum Level Detected (ppb)	Maximum (ppb)	Average* (ppb)
Whole Peanuts						
CFIA	***2011-2013***	***5***	***5 (100)***	***16***	***43***	***28***
HC[22]	2012	14	14 (100)	24	41	32
FDA[14]	2011	3	1 (33)	< LOD	28	NA
Peanut Butter						
CFIA	***2011-2013***	***35***	***35 (100)***	***25***	***240***	***93***
HC[22]	2012	14	14 (100)	60	133	100
FDA[14]	2011	5	5 (100)	64	125	94

*Average of positive results only

Other Nuts/Other Nut Butters

A total of 26 other nuts and 94 other nut butters were tested for acrylamide. This included all nuts other than peanuts (e.g., almonds, cashews, macadamia, pistachios, pecans, walnuts) as well as seed spreads (e.g. tahini). Table 4 summarizes the current FSAP as well as HC and FDA data on acrylamide levels in other nuts and other nut butters.

Of the 26 whole nuts, 10 samples (38%) tested positive for acrylamide, with maximum and average levels of 220 ppb and 41 ppb respectively. No samples of pecans or walnuts tested positive for acrylamide. Of the samples that tested positive, pistachio and macadamia whole nuts had the lowest average levels of acrylamide whereas almonds had the highest average level (349 ppb). Compared to the HC and FDA data, the current survey data for other whole nuts has lower maximum and average acrylamide levels as well as a lower positive rate. Note that the HC and FDA surveys sampled only almonds and cashews.

Table 4. Summary of FSAP, HC and FDA surveys examining acrylamide levels in other nuts/nut butters

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum Level Detected (ppb)	Maximum (ppb)	Average (ppb)*
Other Nuts (whole)						
CFIA	***2011-2013***	***26***	***10 (38)***	***7***	***220***	***41***
HC[22]	2012	26	26 (100)	17	749	379
FDA[14]	2011	5	4 (80)	236	457	320
Other Nut Butters						
CFIA	2011-2013	94	76 (81)	5	1800	164

*Average of positive results only

Of the 94 other nut butters, 76 samples (81%) tested positive for acrylamide, with maximum and average levels of 1800 ppb and 164 ppb, respectively. No samples of pecan or walnut butters tested positive for acrylamide. Of the samples testing positive, macadamia nut butters had the lowest average levels of acrylamide, whereas almond butters had the highest average levels, consistent with the results for whole nuts.

Syrups/Molasses

Syrups included corn, table, and pancake syrups (maple syrup was not sampled). Acrylamide levels were generally low in syrups and relatively high and variable in molasses. Table 5 presents a comparison of the acrylamide levels for syrups and molasses in the previous and current FSAP surveys.

Table 5. Summary of FSAP survey data examining acrylamide levels in syrups and molasses

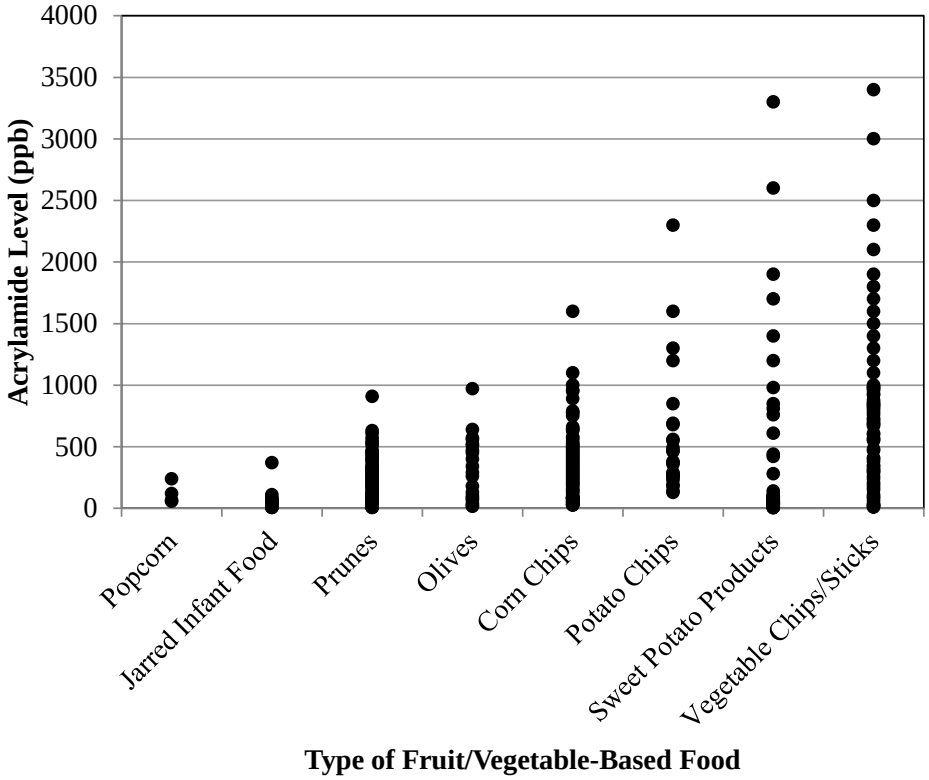
Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)*
Syrup						
CFIA[21]	***2011-2013***	***16***	***1 (6)***	***< LOD***	***17***	***NA***
	2010-2011	22	9 (41)	15	48	27
Molasses						
CFIA[21]	***2011-2013***	***9***	***9 (100)***	***270***	***3200***	***1430***
	2010-2011	7	7 (100)	380	1600	901

*Average of positive results only

Syrups and molasses were not included in Health Canada's Bureau of Chemical Safety[22] survey, the FDA[14,23] surveys, nor to our knowledge in any scientific study, so comparisons to existing data could not be made. Comparing the current and previous FSAP surveys, the positive rate, maximum and average acrylamide levels in syrups were somewhat lower in the current survey. For molasses, the positive rates are identical for the two FSAP surveys. The maximum and average acrylamide levels in molasses are higher in the current survey than in the previous year.

3.2.2. Fruit/Vegetable-Based Foods

The fruit/vegetable-based product group included 14 popcorn samples (popped and un-popped), 29 potato chips, 50 olives, 54 sweet potato products (e.g., canned sweet potatoes, soup, chips), 112 vegetable chips/sticks, 122 jarred infant foods (excluding prune or sweet potato-based infant foods which are reported in those respective categories), 158 corn chips, and 327 prune-based foods (e.g., prunes/dried plums, juice, infant foods). All of the product types had detectable levels of acrylamide. Figure 7 shows the observed acrylamide levels per product type (only positive values are displayed). The observed acrylamide levels ranged from the method reporting limit of 5 ppb to a maximum of 3400 ppb in vegetable chips/sticks.



Note: Only values above the limit of detection are displayed in the graph

Figure 7. Acrylamide levels in fruit/vegetable-based foods by product type (arranged in order of increasing maximum acrylamide levels)

Popcorn

Popcorn included both the unpopped kernels and popped products. Only the popped popcorn contained detectable levels of acrylamide. In both the previous and the current FSAP surveys, popcorn showed low overall acrylamide levels. Table 6 presents a comparison of the acrylamide levels in popcorn products.

Table 6. Summary of FSAP survey and HC/FDA data examining acrylamide levels in popcorn

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average * (ppb)
Popcorn**						
CFIA[21]	***2011-2013***	***14***	***4 (29)***	***58***	***240***	***121***
	2010-2011	19	10 (53)	14	410	146
HC[22]	2012	13	13 (100)	145	303	216
FDA[14]	2011	3	3 (100)	157	446	261

*Average of positive results only

**The CFIA surveys included both popped and unpopped popcorn, whereas the HC and FDA studies focused on popped popcorn

Both the current and previous FSAP survey results agree with studies published by both HC and the US FDA with respect to the maximum acrylamide levels observed. The positive rate in the CFIA surveys, as well as the average acrylamide concentration, is lower than those in the HC and FDA surveys. Note that the CFIA surveys included unpopped popcorn while the HC and FDA surveys included only popped popcorn. For comparison purposes, removal of the unpopped samples from the CFIA surveys leads to a positive rate of 91% for the 2010-2011 survey and 100% for the current survey year.

Jarred Infant Food

The jarred infant food category included 122 samples consisting of squash, carrots, fruit, and mixed vegetables. Sweet potato- and prune-based foods have separate categories for the current survey; therefore, jarred infant foods based on these foods are discussed in the relevant sections. Jarred infant foods had low positive rates for acrylamide (31%), with a minimum level of 7 ppb and a maximum of 370 ppb.

Table 7 summarizes the current survey as well as HC and FDA data for acrylamide in jarred infant food. The CFIA maximum detected level of acrylamide (370 ppb) is higher than the reported FDA results; however the detection rate (31%) is lower. The average levels of acrylamide for the CFIA and FDA studies are generally consistent, despite disparity in maximum levels and detection rates.

Table 7. Summary of FSAP survey and HC/FDA data examining acrylamide levels in jarred infant food

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average * (ppb)
Jarred Infant Food						
CFIA	***2011-2013***	***122***	***38 (31)***	***7***	***370***	***41***
FDA[14,23]	2011	90	47 (52)	10	89	32
	2011	8	5 (63)	17	39	25

*Average of positive results only

Prune-based Foods

Prune-based foods included 327 samples of jarred infant food, prune juices/nectars, and whole prunes (dried and pitted). Acrylamide was detected in 95% of all prune products tested in the current survey, with a maximum level of 910 ppb and an average of 133 ppb.

Table 8 summarizes the FSAP, HC, and FDA survey data for acrylamide in prune-based foods. The maximum acrylamide level for the current FSAP survey is higher than that of the previous CFIA study; however, the average is lower. In general, the acrylamide levels detected in prune-based foods are consistent between FSAP survey years and agree well with the HC and FDA survey data.

Table 8. Summary of FSAP survey and HC/FDA data examining acrylamide levels in prune-based foods

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average* (ppb)
Prune-Based Foods						
CFIA[21]	***2011-2013***	***327***	***312 (95)***	***6***	***910***	***133***
	2010-2011	28	28 (100)	15	580	142
HC[22]	2012	57	55 (96)	58	916	177
FDA[14]	2011	6	6 (100)	31	267	158

*Average of positive results only

Olives

The olives category included a variety of types (e.g., black, green, kalamata), excluding stuffed olive products. A total of 50 olive products were sampled, with 22 (44%) testing positive for acrylamide. The average acrylamide level for olives was 336 ppb, with minimum and maximum levels of 15 ppb and 970 ppb respectively. Table 9 presents a summary of the current survey and HC/FDA data for acrylamide in olives. The maximum and average acrylamide levels in olives for the current survey are higher than the HC survey but lower than the FDA study.

Table 9. Summary of FSAP survey and HC/FDA data examining acrylamide levels in olives

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average* (ppb)
Olives						
CFIA	***2011-2013***	***50***	***22 (44)***	***15***	***970***	***336***
HC[22]	2012	27	21 (78)	50	668	259
FDA[14]	2011	26	10 (39)	19	1925	598

*Average of positive results only

Corn/Vegetable/Potato Chips

Table 10 summarizes the FSAP survey data and HC/FDA values for acrylamide levels in corn, vegetable, and potato chips. A total of 158 corn/tortilla chip products were sampled, with an average acrylamide level of 335 ppb and minimum/maximum levels of 25 ppb and 1600 ppb, respectively. All 158 corn chips sampled tested positive for acrylamide, consistent with the previous FSAP survey as well as with the HC and FDA studies. The CFIA surveys show higher average and maximum levels of acrylamide in corn chips than the HC and FDA studies. The average acrylamide levels detected for the different FSAP survey years were similar.

Vegetable chips consisted of 112 samples, where the products were comprised of vegetables such as beets, carrots, and parsnip. The acrylamide levels detected ranged from 9 ppb to 3400 ppb, with an average level of 921 ppb. Vegetable chip products had high positive rates for acrylamide (99%), consistent with the previous FSAP, HC, and FDA surveys. The maximum acrylamide level for the current survey is higher than the HC and FDA surveys; however, the average falls within the range previously reported. When comparing the data for vegetable chips, it is important to note that several samples contained potato/potato flour as the primary ingredient. These samples contained the highest levels of acrylamide detected for the vegetable chip category, consistent with the high rates of acrylamide previously detected in potato chips[14,23].

Table 10. Summary of FSAP survey and HC/FDA data examining acrylamide levels in corn, vegetable, and potato chips

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average* (ppb)
Corn Chips						
CFIA[21]	***2011-2013***	***158***	***158 (100)***	***25***	***1600***	***335***
	2010-2011	77	77 (100)	11	1200	329
HC[22]	2012	40	40 (100)	34	495	245
FDA[14]	2011	11	11 (100)	65	282	159
Vegetable Chips						
CFIA[21]	***2011-2013***	***112***	***111 (99)***	***9***	***3400***	***921***
	2010-2011	1	1 (100)	< LOD	750	NA
HC[22]	2012	8	8 (100)	1419	2924	1863
FDA[14]	2011	7	7 (100)	30	1340	594
Potato Chips						
CFIA[21]	***2011-2012***	***29***	***29 (100)***	***130***	***2300***	***536***
	2010-2011	59	59 (100)	57	1300	466
HC[22]	2012	82	82 (100)	61	4660	503
FDA[14]	2011	62	62 (100)	117	2762	624

*Average of positive results only

All 29 potato chip products tested positive for acrylamide, with maximum and average acrylamide levels of 2300 and 536 ppb respectively. In comparison to the previous FSAP survey, the maximum and average acrylamide levels are higher. However, the current survey data agrees well with HC and FDA studies on acrylamide in potato chips.

Sweet Potato Products

Sweet potato products included 54 samples of canned whole potatoes, soups, infant foods, and snacks such as chips. Acrylamide levels in sweet potato products ranged from a minimum of 5 ppb to 3300 ppb, with an average level of 435 ppb. Table 11 summarizes the current FSAP survey as well as HC and FDA data for acrylamide in sweet potato products. The positive rate for acrylamide detection was high (94%), consistent with data from HC and FDA. The maximum acrylamide level detected in the current CFIA survey is slightly higher than the HC and FDA studies but the average is lower. Sweet potato chips had the highest levels of acrylamide, with a maximum of 3300 ppb, whereas soups and canned sweet potatoes had the lowest levels. This is consistent with both the HC and FDA surveys on acrylamide in sweet potato products.

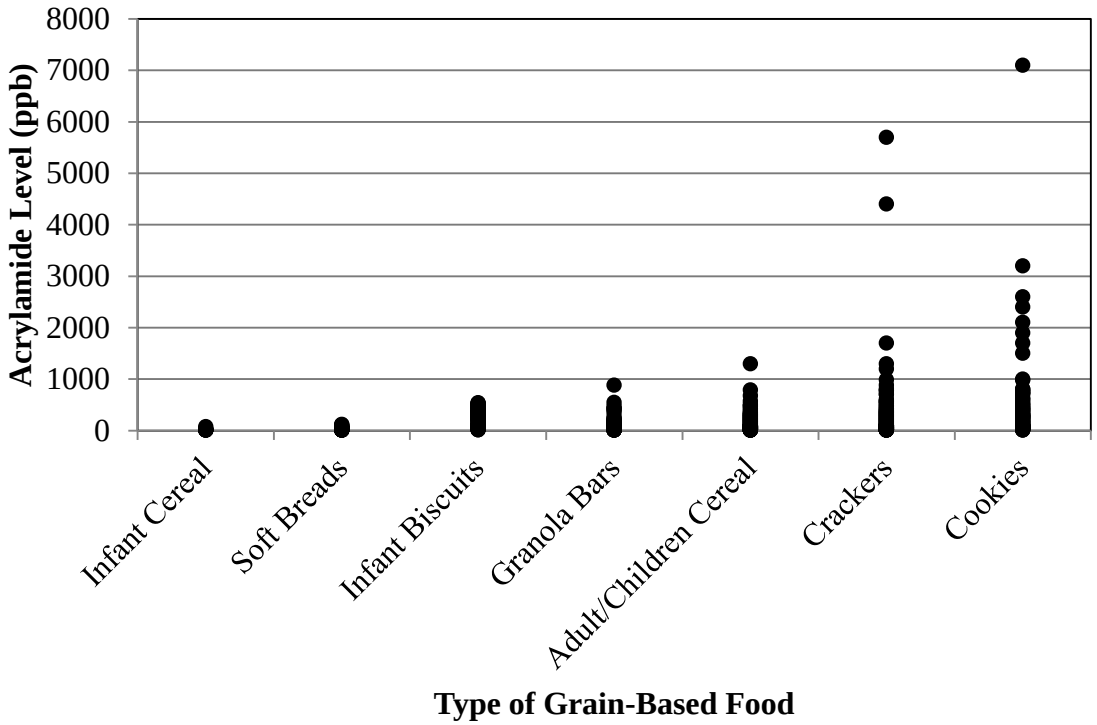
Table 11. Summary of FSAP survey and HC/FDA data examining acrylamide levels in sweet potato products

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average* (ppb)
Sweet Potato Products						
CFIA	***2011-2013***	***54***	***51 (94)***	***5***	***3300***	***435***
HC[22]	2012	31	31 (100)	32	2924	525
FDA[14]	2011	8	8 (100)	37	2762	754

*Average of positive results only

3.2.3. Grain-Based Foods

The grain-based product group included 29 infant cereals, 91 infant biscuits (e.g. teething biscuits, arrowroot biscuits), 98 soft breads (e.g. bread loaves, bagels, English muffins), 105 cookies, 144 granola bars, 257 adult/children's breakfast cereals, and 316 crackers (including crispbreads and croutons). All product types had detectable levels of acrylamide, ranging from the method reporting limit of 5 ppb to a maximum of 7100 ppb in cookies. The percentage of samples with detectable levels of acrylamide was high for all product types except infant cereals, with only 48% testing positive. Figure 8 presents the detectable levels observed by product type in order of increasing maximum acrylamide content.



Note: Only values above the limit of detection are displayed.

Figure 8. Acrylamide levels in grain-based foods by product type (arranged in order of increasing maximum acrylamide level)

Infant Cereal and Infant Biscuits

Table 12 summarizes the FSAP, HC, and FDA data for acrylamide in infant cereal and biscuits. A total of 91 infant biscuits (e.g., arrowroot cookies, teething biscuits) were tested for acrylamide. Infant biscuits generally had low levels of acrylamide with maximum and average acrylamide levels of 540 and 223 ppb respectively. The current data for acrylamide in infant biscuits agree well with the previous FSAP, HC, and FDA surveys.

A total of 29 infant cereals were tested for acrylamide, with only 14 (48%) testing positive. Infant cereals had very low levels of acrylamide, with an average of 18 ppb. The FSAP survey data agrees well with the HC and FDA data except for a higher positive rate for infant cereals. Note that the HC and FDA LODs were 10 ppb, potentially explaining the higher positive rates for the FSAP surveys.

Table 12. Summary of FSAP survey and HC/FDA data examining acrylamide levels in grain-based infant foods

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average* (ppb)
Infant Biscuits						
CFIA[21]	2011-2013	91	90 (99)	11	540	223
	2010-2011	35	35 (100)	20	520	179
HC[22]	2012	55	55 (100)	31	1900	295
FDA[14]	2011	9	9 (100)	20	432	173
Infant Cereals						
CFIA[21]	2011-2013	29	14 (48)	7	79	18
	2010-2011	27	13 (48)	9	26	15
HC[22]	2012	6	2 (33)	18	20	19
FDA[14]	2011	6	0 (0)	NA	NA	NA

*Average of positive results only

Soft Breads

The soft breads category included products such as bread loaves, bagels, and English muffins (including all varieties of grain). A total of 98 samples were tested, with 81 (83%) testing positive for acrylamide. The levels of acrylamide detected ranged from a minimum of 7 ppb to a maximum of 120 ppb, with an average level of 31 ppb.

Table 13 summarizes the FSAP, HC, and FDA survey data regarding acrylamide in soft breads. Soft breads had very low levels of acrylamide, regardless of grain type. The maximum and average acrylamide levels detected for soft breads in the CFIA study agree well with the results of HC and FDA surveys. For comparison purposes, only non-toasted bread samples from the HC and FDA surveys were considered relevant.

Table 13. Summary of FSAP survey and HC/FDA data examining acrylamide levels in soft breads

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average* (ppb)
Soft Breads**						
CFIA	***2011-2013***	***98***	***81 (83)***	***7***	***120***	***31***
HC[22]	2012	28	23 (82)	10	79	27
FDA[14]	2011	62	41 (66)	10	130	42

*Average of positive results only

**Only non-toasted samples from the FDA and HC surveys are shown

Granola Bars

A total of 144 granola bars were sampled, including cereal bars, iced/coated bars, and fruit-filled granola products. The majority of granola bars tested positive for acrylamide (97%) with an average level of 91 ppb. There is a lack of scientific information on acrylamide levels in this product type; therefore, there is minimal data available for direct comparison. A Food Standards Agency (FSA) study in the UK reported average levels of acrylamide in granola bars of 135 ppb, slightly higher than the value obtained in the current CFIA survey (91 ppb) [24]. However, the FSA survey included only four samples. The current CFIA survey data may serve as a baseline for acrylamide levels in granola/cereal bar products available in Canada.

Breakfast Cereals

The breakfast cereals category included all varieties of adult/children's breakfast cereals (including oatmeal); data collected for infant cereals are presented above. A total of 257 breakfast cereals marketed toward adults and children were sampled, with 247 (96%) testing positive for acrylamide (Table 14). The acrylamide levels detected in breakfast cereals ranged from a minimum of 5 ppb to a maximum of 1300 ppb, with an average level of 123 ppb.

Table 14 summarizes the FSAP, HC, and FDA survey data regarding acrylamide in breakfast cereals. In comparison to the previous FSAP survey, the current survey reports the same maximum acrylamide level and a slightly lower average. The average acrylamide level also agrees well with data from HC and FDA.

Table 14. Summary of FSAP survey and HC/FDA data examining acrylamide levels in breakfast cereals

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average* (ppb)
Breakfast Cereals						
CFIA[21]	***2011-2013***	***257***	***247 (96)***	***5***	***1300***	***123***
	2010-2011	121	120 (99)	11	1300	168
HC[22]	2012	48	45 (94)	26	407	122
FDA[14]	2011	60	58 (97)	11	1057	156

*Average of positive results only

Cookies/Crackers

A total of 105 cookies (e.g. chocolate chip, peanut butter, shortbread) were tested for acrylamide, with 103 (98%) testing positive (Table 15). The average acrylamide level in cookies was 511 ppb, with minimum and maximum levels of 10 ppb and 7100 ppb respectively. The high positive rate is consistent with previous FSAP, HC, and FDA surveys. The average acrylamide level in cookies for the current survey is higher than the previous FSAP, HC, and FDA surveys. It should be noted that one cookie sample in

particular had the highest acrylamide level detected in this survey (7100 ppb). This value is over 2 times higher than the next highest value for cookies (3200 ppb).

The crackers product category included crackers, crispbreads and croutons. A total of 316 samples were collected, with 313 (99%) testing positive for acrylamide. The average acrylamide level in crackers was 213 ppb with minimum and maximum levels of 6 ppb and 5700 ppb, respectively. The high positive rate is consistent with previous FSAP, HC, and FDA surveys. The average acrylamide level of the current study (213 ppb) is lower than the previous FSAP survey and falls within the range of the HC and FDA survey data. When analyzing the 2011-2013 survey data for crackers, two samples show significantly higher acrylamide levels than the rest of the sample distribution. These two samples are cracker chips, where the primary ingredient is potato. For comparison, removal of these two potato-based cracker samples leads to a new maximum detected value of 1700 ppb. In general, the 2011-2013 acrylamide levels in crackers compare well with the previous FSAP survey data. Table 15 summarizes the FSAP and literature data for acrylamide in cookies and crackers.

Table 15. Summary of FSAP survey and HC/FDA data examining acrylamide levels in cookies and crackers

Study Author	Year	Number of Samples	Number (%) of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average * (ppb)
Cookies						
CFIA[21]	***2011-2013***	***105***	***103 (98)***	***10***	***7100***	***511***
	2010-2011	51	49 (96)	6	620	173
HC[22]	2012	86	86 (100)	12	1100	203
FDA[14]	2011	28	26 (93)	34	955	123
Crackers**						
CFIA[21]	***2011-2013***	***316***	***313 (99)***	***6***	***5700***	***213***
	2010-2011	60	60 (100)	6	2000	396
HC[22]	2012	46	46 (100)	10	511	116
FDA[14]	2011	44	44 (100)	26	1540	245

* Average of positive results only

** Crackers include: crackers, crispbreads, and croutons

4. Conclusions

A total of 2284 samples were tested for acrylamide. Of these samples, 87% (1983) had detectable levels of acrylamide. The detected acrylamide levels ranged from 5 ppb in various commodities to 7100 ppb in cookies. The highest average acrylamide level for a given product type was observed in syrup/molasses (1289 ppb), though elevated levels were also observed in vegetable chips/sticks and cookies.

For similar products, the current CFIA FSAP survey positive rates and acrylamide levels are comparable to the previous FSAP survey, as well as to HC and FDA data.

Currently, no maximum level, tolerance, or standard has been established by Health Canada's Bureau of Chemical Safety for acrylamide levels in food and therefore compliance with a numerical standard was not evaluated in this survey. All the data generated was shared with Health Canada's Bureau of Chemical Safety for use in performing human health risk assessments. Health Canada indicated that, given the chronic nature of the potential hazard represented by acrylamide and considering the overall levels of acrylamide found, the levels of acrylamide observed in this survey would not be expected to pose a safety concern. Health Canada continues to encourage the food industry to further pursue reduction efforts for acrylamide in processed foods. Health Canada's on-going risk management efforts relating to acrylamide in foods may also involve follow-up with food manufacturers when products are found to contain notably and/or consistently elevated levels of acrylamide relative to other, similar foods available on the Canadian market.

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